COMPARISON OF VARIOUS CONDITIONING METHODS FOR RAWINSONDE BALLOONS

Results From the South Pole Station, Antarctica, 1957

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ABSTRACT

Various methods of conditioning the rawinsonde balloon were tried at the Amundsen-Scott IGY Station (South Pole), Antarctica, in an attempt to improve sounding heights. During the dark, cold months, conditioning of the balloon in warm diesel fuel proved significantly better than the conventional conditioning methods. However, with the return of sunlight and the rapid warming of the stratosphere, diesel fuel conditioning was found to be inferior to the boiling water or moist heat-box method of balloon conditioning.

1. INTRODUCTION

With the advent of the International Geophysical Year, various international organizations (World Meteorological Organization, Special Committee for the IGY) voiced the request that all meteorological services attempt to obtain radiosonde flights to 50 mb. on a regular basis. At most of the United States installations this did not present a problem as it was already being accomplished. However, for the United States IGY stations being established in Antarctica it did present an operational problem. All of the evidence available from radiosonde observations made in the Antarctic indicated that the stratosphere over the continent becomes extremely cold during the winter season (approaching −90° C. at 18–20 km.). The deleterious effect of these cold temperatures on the neoprene sounding balloon as reflected in much lower flight altitudes during winter is a matter of record.

In a document distributed by the WMO [1], all phases of the balloon handling, storage, and conditioning problem were discussed. Besides the conventional methods of conditioning the sounding balloon (moist heat-box, immersion in boiling water), the use of petroleum products was suggested as a result of some experiments carried out in the Union of Soviet Socialist Republics. These tests [2] indicated an increase during the cold months of 5–8 km. in the bursting heights of balloons that were conditioned with liquid hydrocarbons.

Due to the advance planning that was necessary for the operation in Antarctica, supplies (including rawinsonde balloons) for some of the stations had to be shipped to Antarctica in 1955 and stored there until the establishment of the permanent bases in the summer of 1956–57. Storage of neoprene balloons at low temperatures (in this case 0° to −50° C.) results in a partial loss of elasticity. It was not at all surprising, therefore, that these balloons did not attain the expected heights and very frequently failed to reach the minimum of 50 mb. requested for the IGY.

2. EQUIPMENT

With two exceptions, all of the balloons used at the South Pole Station during the period reported here were 500-gram balloons (both day and night flight) dated 1955. The night flight balloons were used from the initiation of the program until September 25, the day flight balloons from September 12 to November 30. These balloons had been stored at McMurdo, Antarctica for nearly a year before they were airdropped to the South Pole Station. The balloons in use at the beginning of the program had been in warm storage (+20° to +25° C.) for about a month before use, and immediately prior to use the balloons were conditioned in a heat-box at +55° C. for 12 to 24 hours. For the moist heat conditioning, pans of water were placed on the floor of the heat-box and the balloons conditioned for 36 hours at a temperature of about +60° C.

A Gill low-pressure hydrogen generator was used for manufacturing the inflating gas. Approximately 20 to 30 minutes were required to inflate the balloon to a free lift of 1,900 to 2,300 grams. Whenever two or more charges were required to get a usable balloon, the second and succeeding charges produced a noticeable increase of

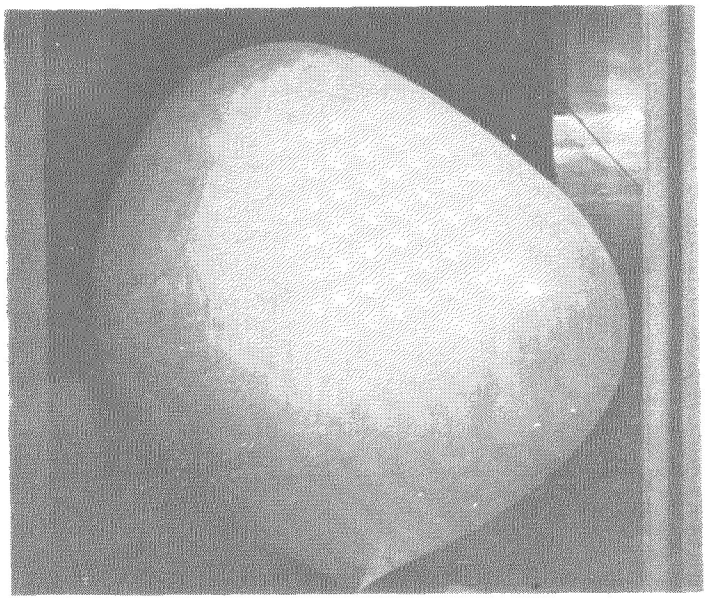

FIGURE 1.—Typical non-symmetrical balloon. This balloon was used for flight no. 238, 1200 GMT, July 29, 1957. It burst at 120 mb., 13,200 m. The largest diameter is about 8.5 ft.

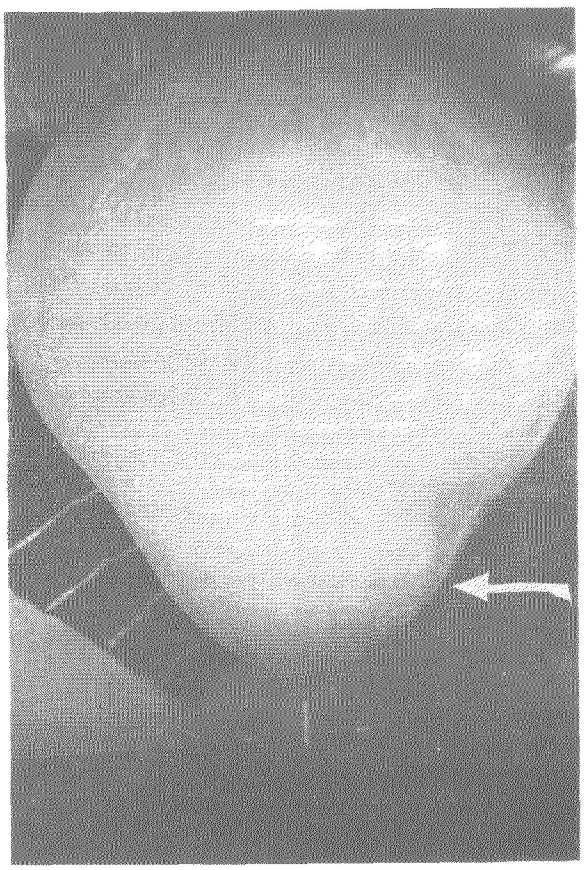

FIGURE 2.—Typical non-symmetrical balloon. This balloon was used for flight no. 329, 0000 GMT, September 13, 1957. It burst at 153 mb., 12,021 m. The arrow indicates the center line of the balloon.

steam along with the hydrogen, the steam subsequently condensing on the inner walls of the balloon. Depending on the temperature of the inflation room the condensed vapor was either water droplets or ice crystals. A gravity condenser was used in the gas line; for second or third inflations a second condenser can was used with both cans packed in snow. Nevertheless, many flights were made with water or ice crystals completely covering the inner walls of the balloon. It is worth noting that a large percentage of such flights reached average or better altitudes. During the period May through October, 56 flights were made with second and third inflation balloons with an average bursting level of 68.2 mb. This compares with an average bursting level of 64.1 mb. for single inflation balloons during the same period. For three of these months the second and third inflation balloons had higher termination heights than the single inflation balloons.

Throughout the year, better than half of the balloons inflated were non-symmetrical in shape. Figures 1 and 2 show typical examples. Generally this type of balloon developed a bulge which inflated at the expense of the rest of the balloon (note the position of the center line of the balloon in the second photograph). In nearly every case a well-shaped symmetrical balloon gave a high flight, while there was considerable variability in the performances of the non-symmetrical balloons.

3. FLIGHT TESTS

The first rawinsonde flight was made at the South Pole Station on March 27, 1957, at a time when the stratosphere was already appreciably cooled from its very warm summer state (compare figs. 3 and 8), although it was no colder than is normally found at a mid-latitude station. Despite this, the average sounding height for the first month was sub-par, averaging near 16.5 km., and dropping even lower in late April. Various conditioning methods were then tried. Immersion in gasoline had been suggested but this method was given only a short test because of the fire hazard. Instead, Arctic diesel fuel was tried as a conditioner. Soaking of the balloon in diesel fuel (or gasoline) caused swelling and increased the elasticity of the neoprene and immediately resulted in improved sounding heights.

TABLE 1.—*Results of soundings with balloons conditioned by three methods during trial period, May 1–7, 1957*

Number of flights	Conditioning method	Average pressure at burst (mb.)	Average height at burst (m.)	Average temperature at burst (° C.)	Pressure at burst: Best flight (mb.)	Pressure at burst: Worst flight (mb.)
6	Dry heat-box	125.5	14,038	−68.9	70	211
5	Diesel fuel	42.4	20,447	−74.8	23	74
2	Gasoline	------	------	−70.5	89	234

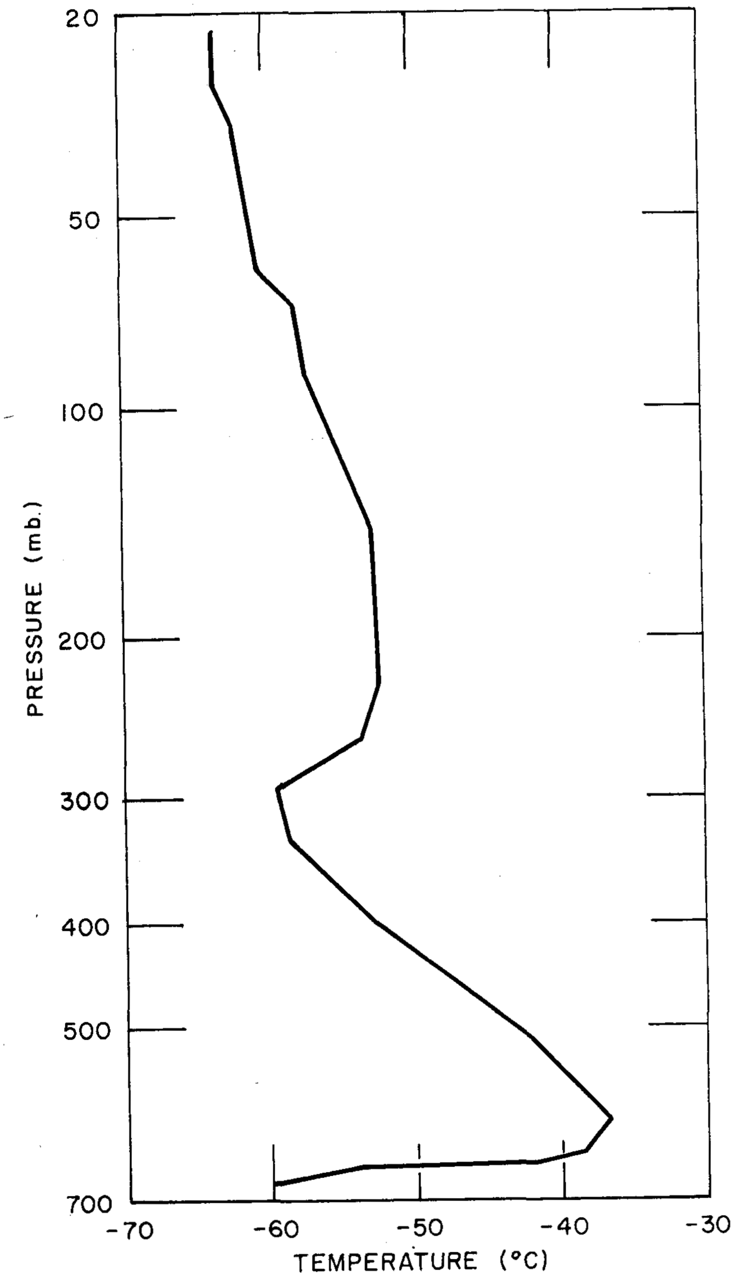

Figure 3.—Typical early fall sounding, 0000 GMT, April 4, 1957.

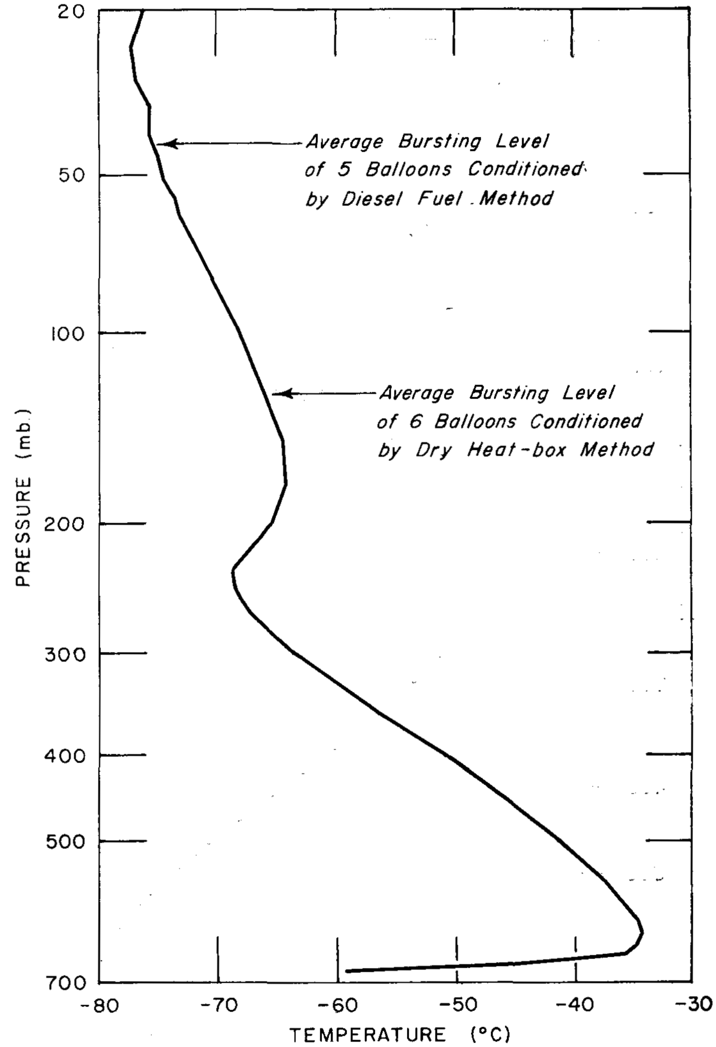

Figure 4.—Mean sounding for May 1–10, 1957.

On May 1, the first flight was made with a balloon conditioned by immersion in warm diesel fuel. For a period of a week following this initial flight successive soundings were made using balloons conditioned by three different methods. The results are summarized in table 1. In the following tables only flights terminated by bursts are considered.

Although the sample was small the results were impressive. Figure 4 is a plot of the mean sounding for the period May 1–10, with some of the information from the table.

To look a bit further into the suggestion that the diesel conditioning improved the sounding heights, 22 heat-box flights immediately preceding the above trial period were compared with the 22 diesel flights immediately after the trial period. The results are summarized in table 2.

These statistics are more impressive when it is realized that the stratosphere was colder for the diesel balloons than for the dry-heat balloons. This is illustrated in figure 5.

Table 2.—*Comparison of soundings with balloons conditioned by heat-box method (April 18–May 1, 1957) and by diesel fuel method (May 7–23, 1957)*

Number of flights	Conditioning method	Average pressure at burst (mb.)	Average height at burst (m.)	Average temperature at burst (° C.)	Pressure at burst: Best flight (mb.)	Pressure at burst: Worst flight (mb.)
22	Dry heat-box	86.6	16,205	−64.8	50	127
22	Diesel fuel	33.3	21,751	−75.7	11	59

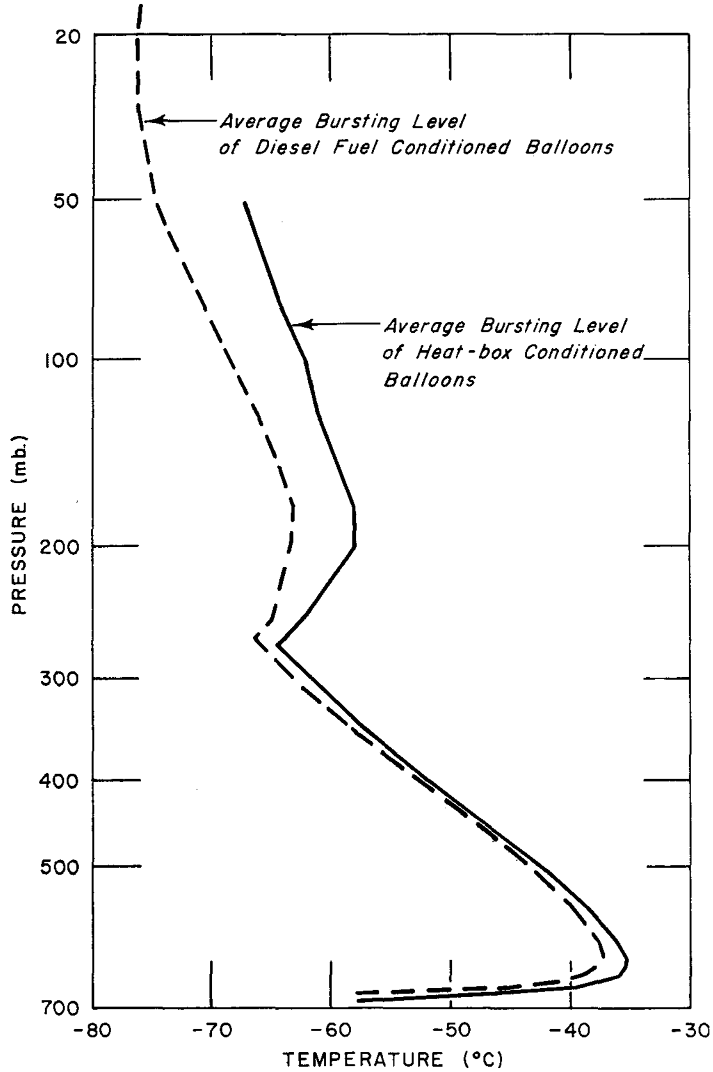

FIGURE 5.—Mean sounding with balloons conditioned by heat-box method, April 18–May 1, 1957 (solid line) and by diesel fuel method, May 7–23, 1957 (dashed line).

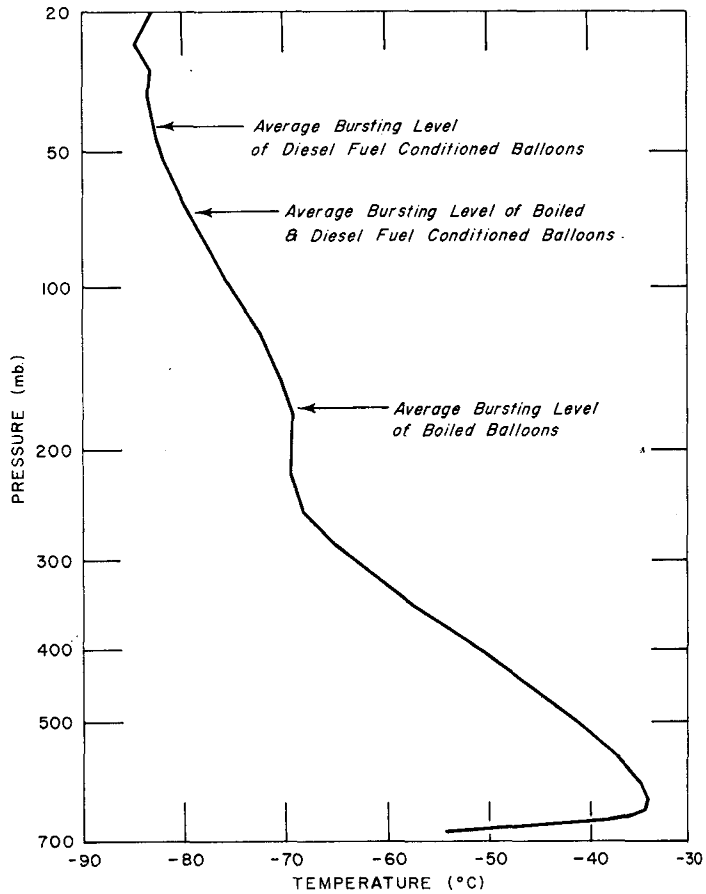

FIGURE 6.—Mean sounding for June 21–30, 1957.

In mid-June a series of flights was made to compare diesel fuel conditioning with the more conventional boiling water method of conditioning. The tests also included a third method—immersion of the balloon in boiling water followed by immersion in diesel fuel. Table 3 presents these results.

TABLE 3.—*Comparison of soundings with balloons conditioned by boiling water and by diesel fuel, June 17–30, 1957*

Number of flights	Conditioning method	Average pressure at burst (mb.)	Average height at burst (m.)	Average temperature at burst (° C.)	Pressure at burst	
					Best flight (mb.)	Worst flight (mb.)
4	Boiling water	169.0	11,742	−70.1	135	200
10	Boiling water and diesel fuel	69.1	17,588	−79.0	32	154
10	Diesel fuel	42.7	19,945	−82.7	19	77

Once again the sample was small. The test was terminated because of the consistently poor flights obtained with the boiled balloons. Figure 6 is a plot of the mean sounding for the period June 21–30 indicating the condition of the stratosphere during this test period.

Diesel fuel conditioning was used throughout the winter and early spring with good results. During these months, a few flights were made with dry-heat conditioned balloons with poor results in every instance. Figure 7 is a plot of two soundings, one with a cold troposphere and the other with a cold stratosphere, typical of the atmosphere through which the balloons were ascending in the period July through September.

TABLE 4.—*Comparison of soundings with balloons conditioned by three methods, November 1957*

Number of flights	Conditioning method	Average pressure at burst (mb.)	Average height at burst (m.)	Pressure at burst	
				Best flight (mb.)	Worst flight (mb.)
35	Diesel fuel	76.5	19,060	18	242
10	Boiling water	22.7	26,458	14	34
9	Moist heat-box	43.9	23,859	15	142

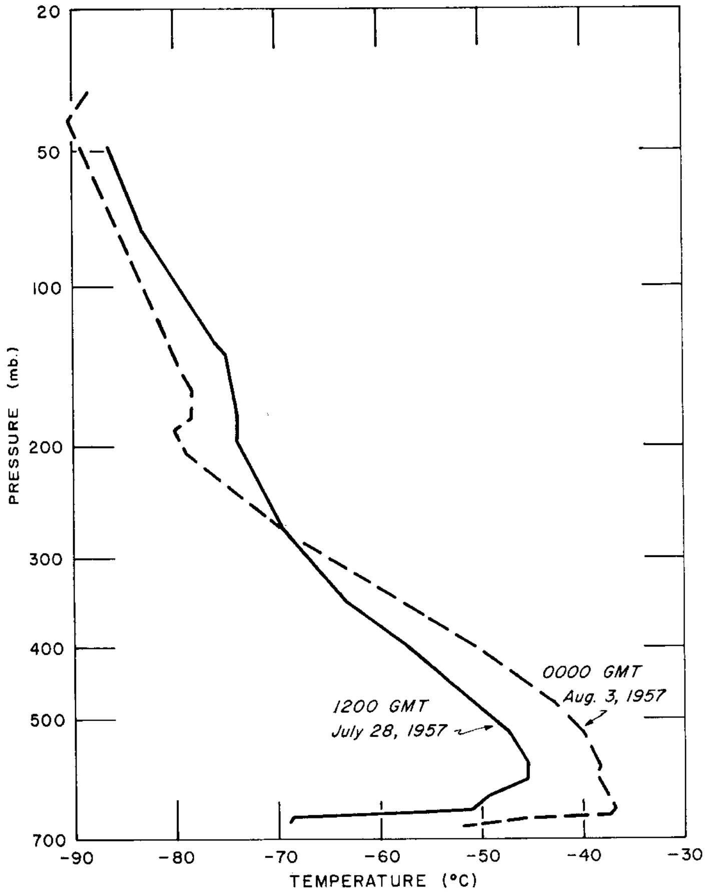

FIGURE 7.—Typical late winter soundings, 1200 GMT, July 28, 1957 (solid line) and 0000 GMT, August 3, 1957 (dashed line).

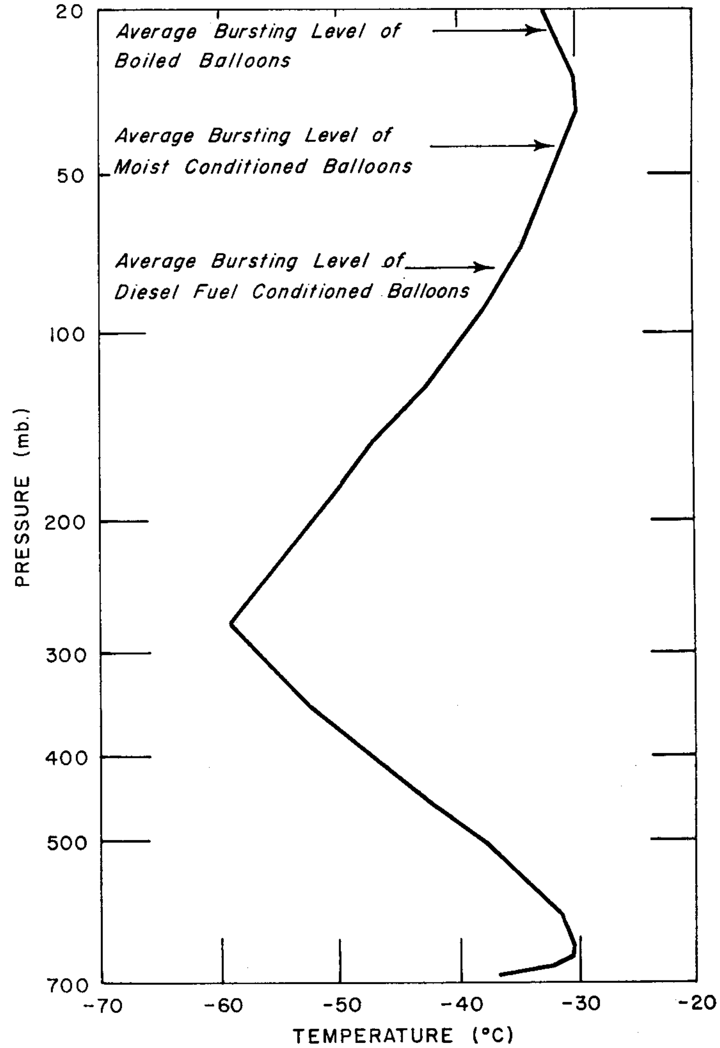

FIGURE 8.—Mean sounding for November 1957.

During the month of October the Antarctic stratosphere undergoes a marked warming, beginning and being most marked at the highest levels sounded. During October 1957 at the South Pole Station, the temperature at 20 mb. warmed from −67° C. on the 1st to −24° C. on the 30th, nearly 1.5° C. per day. With the warmer stratospheric temperatures the bursting heights of the balloons began to rise rapidly. However, during the first half of November there was an indication that the diesel-conditioned balloons were no longer producing consistently high flights. Significantly better flights were made at this time by using balloons conditioned by immersion in boiling water. Table 4 presents the results for November and includes both diesel conditioning and conditioning with boiling water along with some results from balloons treated in a moist heat-box (relative humidity 100 percent).

Figure 8 is the mean sounding for the month of November 1957. It can be seen that the stratosphere was quite warm; temperatures below −70° C. were seldom encountered.

Table 5 summarizes the results from all flights for the period March 27 to November 30, 1957, tabulated according to the different conditioning methods employed.

4. REMARKS

No tests were made to determine the optimum temperature of the diesel fuel in which the balloons were conditioned although this point did not appear critical. In practice the temperature of the diesel fuel ranged from about −10° C. to +40° C. Several checks were made of the effect of prolonged immersion in the diesel fuel and a few flights were made with good results using balloons that had been immersed for 24 hours. These balloons exhibited extreme swelling (the necks swelled to nearly twice the diameter of an untreated balloon) and were very fragile. From the limited evidence it did not appear that lengthy immersion (greater than ½ hour) improved the balloons' performance. Although the diesel-conditioned balloons were probably more fragile than dry bal-

TABLE 5.—*Comparison of all soundings classified according to balloon conditioning methods used, March 27 to November 30, 1957*

Month	Balloon type	Average pressure at burst (mb.)	Average height at burst (m.)	Number of burst flights	Total number of flights	Average height of all flights (m.)	Balloon conditioning method
March	Night flight		16,005	4	5	14,091	Heat-box.
April	Night flight	83.4	16,652	38	46	15,475	Heat-box.
May	Night flight	125.7	13,969	7	7		Heat-box.
		161.5	12,622	2	2		Gasoline.
		36.5	21,268	29	42		Diesel fuel.
				38	51	18,652	
June	Night flight	42.6	20,158	40	56		Diesel fuel.
		69.1	17,588	10	10		Boiling water and diesel fuel.
		169.0	11,742	4	4		Boiling water.
		333	7,637	1	1		Heat-box.
				55	*71	18,243	
July	Night flight	84.0	16,400	65	70		Diesel fuel.
		218	10,025	1	1		Lubricating oil.
				66	*71	16,102	
August	Night flight	84.6	15,885	60	62	16,010	Diesel fuel.
September	Night flight and day flight	73.0	17,123	56	61		Diesel fuel.
		340	7,072	1	1		Heat-box.
				57	*62	16,601	
October	Day flight	44.7	20,208	58	61	20,034	Diesel fuel.
November	Day flight	76.5	19,060	35	36		Diesel fuel.
		22.7	26,458	10	12		Boiling water.
		43.9	23,859	9	11		Moist heat-box.
				54	59	20,603	
March 27–November 30, 1957					488	17,688	

*Includes special World Day soundings.

loons, successful releases were regularly made (through overhead doors) in winds of 20–30 knots.

Martin, Mandel, and Stiehler [3] made patch tests of neoprene balloons and concluded that the two important properties in determining the flight elevations of the balloons were the flaccid length (uninflated length) of the balloon and the elongation of the neoprene film (ratio of the final to initial length of a line drawn on the film). Their equation for predicting the flight elevation is:

$$h = 43.8 \log (E_B L_O) - 86.3$$

where h is the bursting elevation in kilometers, E_B is the elongation of the film, and L_O is the flaccid length of the balloon in inches. This equation used with the data from table 2 of the present paper indicates an increase of about 30 percent in the elongation of the neoprene film of the diesel-treated over the untreated balloons. The effectiveness of various conditioning methods could be checked in the laboratory by using the techniques developed by Martin, Mandel, and Stiehler.

5. CONCLUSIONS

Although the test samples reported in this paper were necessarily small, certain features appear sufficiently consistent to warrant the following conclusions:

1. Soaking the sounding balloon (both inside and out) in diesel fuel resulted in definitely higher flights during the dark, cold months, and possibly will be effective in the Antarctic and Arctic [1] when upper-air temperatures are colder than −70° C.

2. During the cold months, boiling water or dry-heat conditioning of the balloon were inferior conditioning methods.

3. However, with an atmosphere (above the surface inversion) where the coldest temperatures were −70° C. or higher, conditioning of the balloon by immersion in boiling water [2] or by exposure in a moist heat-box were definitely superior to diesel fuel conditioning.

4. Although the conditioning process is very important, the quality and condition (considering storing and handling) of the balloon are of equal importance.

[1] According to the Instrumental Engineering Division, U.S. Weather Bureau, there is some recent evidence from limited tests in the Arctic which appears to show that balloons that have had a greater amount of post plasticizing than those used at the South Pole Station do not respond to the diesel fuel conditioning.

[2] Also according to the Instrumental Engineering Division, there is some recent evidence from limited tests which indicates that balloons that have been heavily post plasticized by the manufacturer react unfavorably to the boiling water method of conditioning.

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